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Deposition from Se-Sb solution for Solar Cell use

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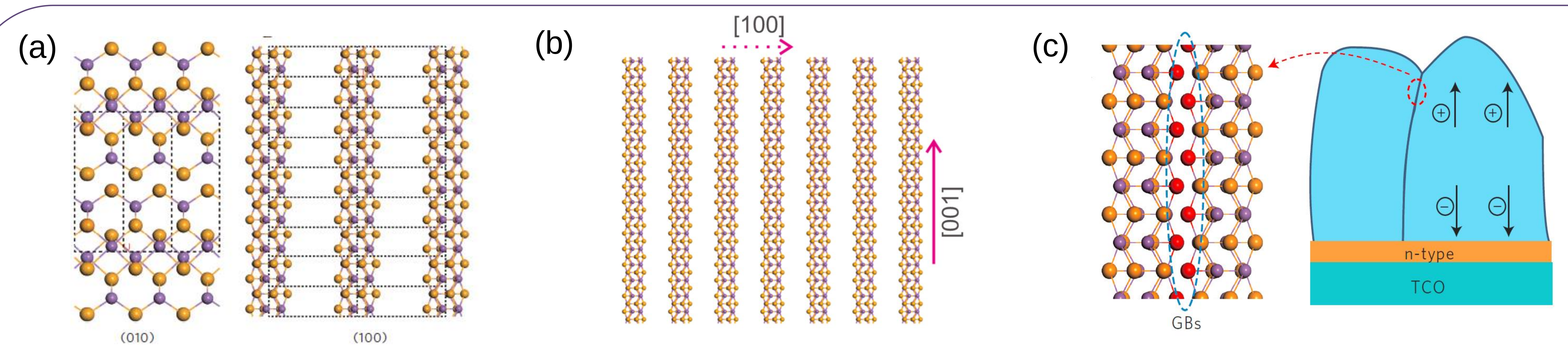
Introduction

One of the limiting factors in the assimilation of solar technologies is the high financial and energetic cost of creating the material from which the cell is made. Another factor that needs constant improvement is the efficiency and overall performance of the cell itself. The need for less-expensive solar cells strongly depends on the discovery of new materials and processes. One way to reduce the cost is to use materials that can be deposited from a low-temperature solution. We investigated the crystallinity and microstructure of antimony selenide deposited by spin coating from an organic solution. Using a recently published method, we used a thiol– amine solvent mixture to dissolve both antimony and selenium under ambient conditions, specifically ethylenediamine and 2-mercaptoethanol, and formed an "ink" of Sb–Se precursor solution. We later used it in spin coating and applied a thermal treatment to form a thin film. This method provides a low cost, simple, and non-toxic process to form semiconductor materials suitable for photovoltaic application.

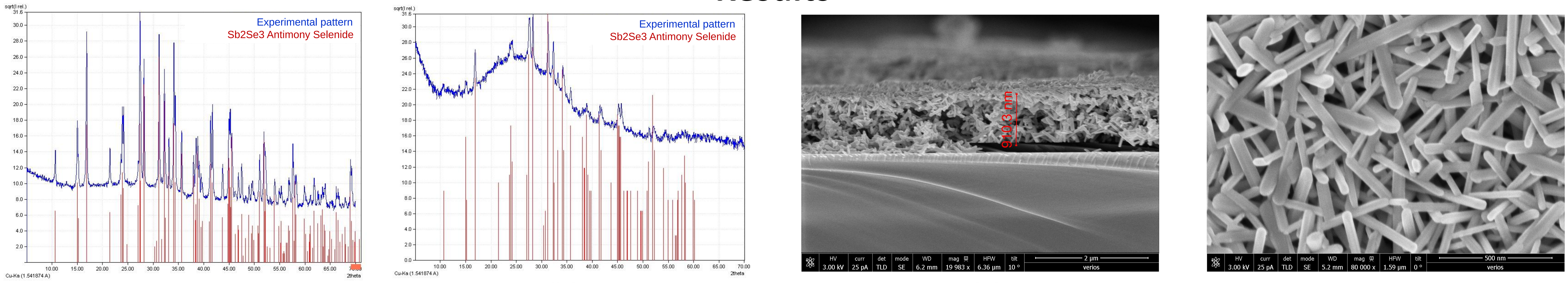


Antimony Selenide has a 3D orthorhombic structure that is composed from 1D ribbons. As long as the ribbons are oriented properly, the small van der Waals coupling between the ribbons cause the grain boundaries to be benign and reduce recombination losses.
Figure 1 [1] : (a) no breaking of the Sb–Se bonds resulting in no dangling bonds (b) Ribbons stacked in parallel (c) No recombination loss at the grain boundaries as long as the ribbons are oriented vertically onto the substrates.

Method

(1) Sb-Se solution (0.5–1 mL) was drop cast onto a clean glass wafer, on a heating plate inside a glove box under nitrogen environment. Thermal treatment- 10 min heating to 100 °C, 5 min at 100 °C, 20 min heating up to 250 °C, cooling down to room temperature.
(2) Sb-Se solution was diluted (1 vol solution : 3 vol en) for spin coating which was performed outside the glove box, under flowing nitrogen. Using glass and silicon wafers that were previously cleaned via Piranha solution with the following conditions:
acceleration = 770 rpm s^{-1},1250 rpm, 4 min.
The films were then heated to 250 °C using a controlled heating plate and underwent the same thermal treatment once again.

Results



(a) (b) (c) (d)

Figure 2: (a) Initial XRD result, from method (1) indicates the presence of antimony selenide in amorphous and crystalline phase. (b) XRD result, from method (2) using glass wafer shows poor fit and a significant amorphous part. (c) SEM cross section results after spin coating on silicon wafer. (d) High-magnification SEM image showing the fully interconnected nanostructure of an Sb_2Se_3 film spin coated on silicon wafer.

Conclusions

The process that was conducted under nitrogen environment, outside of the glovebox, while using a controlled heating plate, yielded results with low fitting to the XRD given pattern. In addition, from the XRD examination there is a significant large amorphous phase.
Using spin coating requires an adjustment between wafer size, amount of solution and dilution ratio.

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References

[1] Y. Zhou, L. Wang, S. Chen, S. Qin, X. Liu, J. Chen, D.-J. Xue, M. Luo, Y. Cao, Y. Cheng, E. H. Sargent and J. Tang, Nat. Photonics, 2015, 9, 409–415